

10.—CONTRIBUTIONS TO THE MINERALOGY OF
WESTERN AUSTRALIA.

Series XI.

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(1)—ANAUXITE, RAVENSTHORPE*, S.W.

The name anauxite was originally given to a clay mineral from Bilin, Czechoslovakia, by Breithaupt in 1838. Hintze in his monumental "Handbuch" gives it a scant three lines amongst a number of non-specific hydrous silicates. Doelter gives it a little more space but classifies it with cimolite, another indefinite mixture. In recent years, however, the name has been revived in the United States, and given specific rank with monoclinic crystallisation and the constitution $2\text{H}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 3\text{SiO}_2$, which differs only from that of kaolinite, nacrite, dickite and metahalloysite, by the addition of one molecule of silica. It forms typically the final product of the weathering or hydrothermal alteration of biotite. In view of its origin there is a doubt whether the third molecule of silica is combined with the other constituents or exists uncombined, but in intimate admixture, as chalcedony or opal.

An opportunity to examine this point came when a specimen of typical anauxite was sent me from Ravensthorpe. It consisted of a rather friable mass of soft, creamy white scales which reach a maximum diameter of four millimetres. They have a hardness of 1, are opaque except in thin flakes under the microscope, and have a pearly lustre. The composition given below indicates that they are pseudomorphous after titaniferous biotite. The second column gives the true composition of the clay mineral after rejecting chalcedony and rutile, in which form all the titanium was found to be present.

*Lat. $33^\circ 31'$ S., Long. $120^\circ 3'$ E.

Anauxite, Ravensthorpe and Bilin.

	Ravensthorpe.			Bilin Type.
	Original.	Recalculated.	Molecules.	
SiO ₂ , free	16·86	...	...	...
SiO ₂ , combined	32·28	40·90	681	50·75
Al ₂ O ₃	26·05	33·00	324	33·34
Fe ₂ O ₃	2·37	3·00	12·5	2·45
FeO, MnO	nil	nil	...	...
MgO	·56	·69	17	·27
CaO	·08	·10	2	·32
Na ₂ O	1·36	1·72	28	...
K ₂ O	·16	·20	2	...
H ₂ O +	13·72	17·38	965	11·38
H ₂ O -	2·04	2·58	143	1·26
TiO ₂	4·09	...	...	...
P ₂ O ₅	nil	...	...	...
Total	99·57	99·57	...	99·77

Analysts: H. P. Rowledge.

W. P. Smirnoff.

It will be noticed that only two molecules of silica out of three in the Ravensthorpe mineral were combined, and after rejecting that present as chalcedony or opal, the recalculated composition gives the normal ratio for kaolin and halloysite of 1 to 2 for Al₂O₃ + Fe₂O₃ to SiO₂. The water percentage is nearer that of halloysite than kaolinite. Some of the soda is probably adsorbed, as the underground waters at Ravensthorpe are more or less saline. These facts do not support the contention that anauxite is an independent species.

- References: 1896. Hintze, H.B.d.Mineralogie, 2 p. 1828.
 1917. Doelter, H.B.d.Mineralchemie, 2(2), p. 32, 39, 123-4.
 1928. Allen, *Amer.Minl.*13, p. 145-155.
 1937. Gruner, *Idem*, 22, p. 855-860.
 1938. Machatschki, *Idem*, 23, p. 117-118.

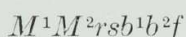
(2) AXINITE, WELD RANGE*, Mur.

In 1937 a prospector (L. M. Ryan) collected a number of fine specimens of axinite from a vein in Precambrian amphibolite somewhere in the Weld Range. The only associated mineral in the vein appears to be quartz, which was in minor amount, and of later growth, often well crystallised round the final cavities.

The enclosing rock is a coarse grained amphibolite consisting largely of a hornblende with extinction angle 20°, and γ , bluish green; β , bottle green to yellowish green; α , very pale yellow. Much plagioclase is present, with a fair amount of zoisite, some ilmenite and a little quartz. This rock is a typical newer, intrusive, amphibolite. Some boulders of an older fine grained amphibolite were picked up in the immediate vicinity.

*Lat. 27° 0'. S., Long. 117° 30'. E.

The axinite is in pure masses up to several pounds in weight, and is of two types. One is massive or microgranular, with G 3.19, and low translucency, about 1 mm. for bright diffused daylight. These characters indicate the prevalence of fluid inclusions. This type appears to be characteristic of the earlier stage of growth but growths from it are more or less well crystallised, with G 3.25 and 3.26, and translucency increased to 5 mm. Both types have a resinous lustre, and vary in colour from greyish white to a medium grey, with at times a slight purplish tint, near Ridgway 69^d. Many of the better crystallised pieces show groups of two or three adjacent faces not easy to correlate with recorded data, but recognised in three cases to be combinations of *Msr*, *Mrb* and *Msrbf*. The latter was a rather perfect crystal of 2.2 grammes, which yielded good measurements for the following faces in order of relative sizes.



M , $\bar{1}\bar{1}0$ r , $\bar{1}\bar{1}1$ s , 201 b , 010 f , 011

The refractive indices measured were N_g , 1.685; N_p , 1.677.

A chemical analysis has yielded the following results:—

Axinite, Weld Range.

SiO ₂	B ₂ O ₃	Al ₂ O ₃	Fe ₂ O ₃	FeO	MnO	CaO
42.42	6.07	17.46	1.47	6.68	3.01	20.09
MgO	TiO ₂	H ₂ O+	Alks.	Total.	G	Analyst
1.50	.12	1.93	nil	100.75	3.26	J. N. A. Grace

This is very close in composition to the original axinite from Bourg d'Oisans in France, and to that at Talbot Bay near Yampi Sound. The analytical figures yield the formula: 1.21 H₂O. 2.00 (Fe,Mn,Mg,Ca)O. 4.04 CaO. 2.04 (Al,Fe)₂O₃. 0.99 B₂O₃. 8.00 SiO₂.

The excess of water is doubtless due to fluid inclusions.

Reference: 1930. Simpson *Jour. Roy. Soc. W.A.*, Vol. 16, p.26-7.

(3) BEIDELLITE, BANGEMALL*, N.W.

Mr. F. G. Forman, Government Geologist, visited the Lyons Valley in 1937, and whilst inspecting McCarthy's old gold diggings 12 miles N.W. of Bangemall, noticed a bright yellow mineral in the auriferous quartz which he submitted to me for examination. If proved to be closely related to, if not identical with, beidellite, a clay mineral first found at Beidell in Colorado in 1925.

The Bangemall mineral forms thin (1 mm.) crusts, which on the surface are smooth or minutely mammilated, and occur on the numerous cracks and cavities in a very ferruginous quartz. It is bright ochre yellow in colour, has a specific gravity of 2.40, hardness 1, and mean refractive index 1.544. Under the microscope it is scaly in structure, translucent and highly birefringent.

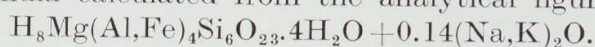
*Lat. 24° 18' S., Long. 116° 55' E.

Some carefully selected mineral was analysed with the following results :—

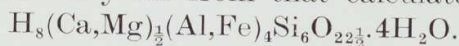
—				Bangemall mineral.		Type Beidellite.	Type Montmorillonite.
				Per cent.	Mols.	Per cent.	Per cent.
SiO ₂	...	...	...	45·92	765	47·28	48·60
Al ₂ O ₃	...	...	...	22·02	216	20·27	20·03
Fe ₂ O ₃	...	...	...	7·53	47	8·68	1·25
MgO	...	...	...	5·15	128	·70	5·40*
CaO	...	...	...	trace	...	2·75	1·72
Na ₂ O	...	...	...	·60	10	·97	present
K ₂ O	...	...	...	·80	8	trace	present
H ₂ O+	...	...	...	10·23	567	19·72	21·52
H ₂ O—	...	...	...	8·17	454	...	...
				100·42		100·37	98·52
Nm	...	...	...	1·544		1·536	1·527
Analyst	...	...	...	C. R. Le Mesurier		Larsen and Wherry	E. V. Shannon

* includes MnO, 0·16.

No sulphate or chloride could be detected in the Bangemall mineral. The formula calculated from the analytical figures is :



This is not very far from that calculated for type beidellite, viz. :



In the higher proportion of monoxides (MgO + CaO) it resembles montmorillonite, of which beidellite is possibly only a ferriferous variety, with some Fe^{III} replacing MgSi.

This is the first record of beidellite for Australia.

The Bangemall beidellite is evidently an epigene mineral of the clay group. There are a large number of these clay minerals whose constitution has not been finally settled, owing to the intimate intermingling in most cases of more than one compound, partly as a mechanical mixture, partly as a true co-crystallisation of isomorphous molecules, partly as an adsorption complex. Some authorities look upon some of them as quite variable mixtures of gels precipitated from complex colloidal suspensions, rather than as definite chemical compounds.

References : 1925. Larsen and Wherry, *J. Wash. Ac. Sci.* 15, p. 465–6 ; Ross and Shannon, *Id.*, p. 467–8.

(4) BEUDANTITE-PLUMBOJAROSITE, Mt. McGRATH†, N.W.

The Belvedere gold and lead mine was discovered in 1936. It lies 8 miles N.N.E. of Mt. McGrath in country composed of metasediments of the Ashburton Series (Precambrian), with which are interbedded basic tuffs and lava flows. Two samples of oxidised ore, with a gangue of quartz and kaolinised schist, were found to have the following metallic contents :—

			Lead.	Copper.	Silver.	Gold.
			Per cent.	Per cent.	Oz. p.t.	Dwt. p.t.
A	...	...	9·70	0·18	7·09	13·80
B	...	...	11·21	0·84	2·66	6·54

†Lat. 22° 40' S., Long. 116° 14' E.

As arsenate and acid soluble sulphate were detected in them, a close examination of the ore was made to determine the forms in which they occurred.

The lode itself consists of a greenstone schist with a network of small quartz veins carrying at depth bunches of galena. Near the surface many of these bunches, reaching several inches in diameter, have been replaced by firm but porous ochre yellow (R 17') to clay coloured (R 17'') masses of what is probably a microscopic intergrowth of beudantite and plumbojarosite, with possibly a little jarosite.

Analyses were made of two slightly different looking specimens, the results being :

Beudantite—Plumbojarosite Mixture, Mt. McGrath.

	Specimen A.		Artificial Mixture.	Specimen B
	Per cent.	Mols.	Per cent.	Per cent.
PbO	24·80	111	25·34	24·25
K ₂ O	·50	5	·42	n.d.
Na ₂ O	·34	6	·29	n.d.
Fe ₂ O ₃	39·57	247	36·54	} 32·03
Al ₂ O ₃	·44	4	...	
SO ₃	14·82	186	17·00	12·37
As ₂ O ₅	10·34	45	10·66	present
P ₂ O ₅	trace	...	...	...
H ₂ O (by diff.) ...	7·76	431	8·25	present
Cl	nil	...	...	...
SiO ₂	1·43	...	1·50	11·60
	100·00	...	100·00	...

Analyst : C. R. Le Mesurier.

Specimen A was typical material, porous, ochre yellow, microgranular, and firmly coherent, with an earthy lustre. Its composition approximates to that of a mixture of beudantite, 66·0 per cent ; plumbojarosite, 23·5 ; jarosite (K₁Na₁), 4·5 per cent ; and quartz, 1·5 per cent. The exact composition of such a mixture is given in col. (3) above.

Fig. 1.

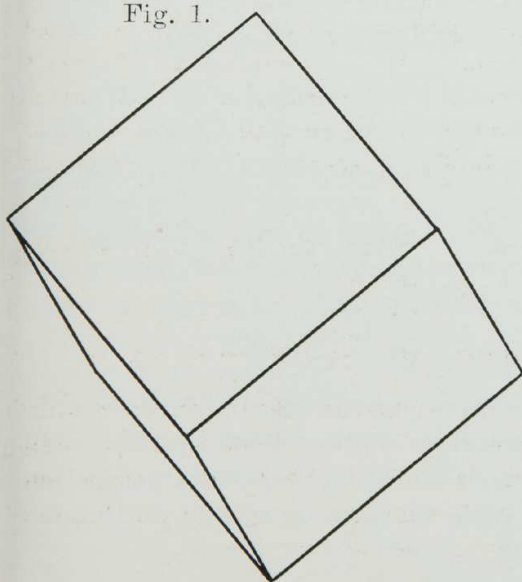


Fig. 2.

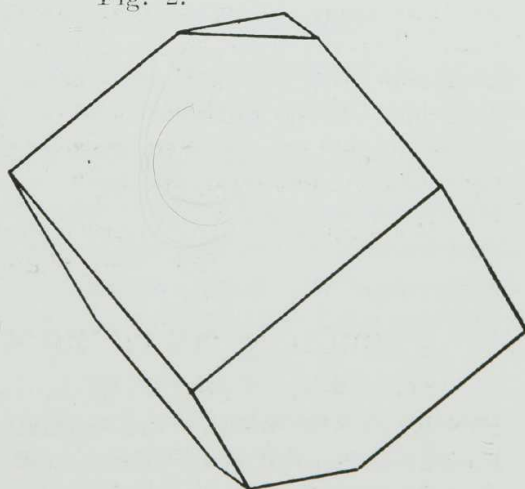


Fig. 3.



Beudantite-Plumbojarosite Crystals Mt. McGrath.

The analysed powder of "A," when viewed under the microscope, was seen to be completely and perfectly crystallised in either (1) simple rhombohedra, (2) rhombohedra slightly truncated by basal planes, (3) flat hexagonal discs, with basal planes connected by rhombohedral faces (figs. 1, 2, 3), and rarely (4) the same connected by hexagonal prism faces. The crystals are all very minute running from 2 to 20 microns in diameter, the average being well under 10 microns. They are transparent and uniform in colour, pale amber to deep amber according to thickness.

As the three species thought to be present are similar in crystallisation and colour, and all have refractive indices higher than methylene iodide, it is not possible to separate them under the microscope. It is probable indeed that the jarosite-natrojarosite molecules are not present as a separate mineral, but are cocrystallised with the beudantite, with which theoretically they should be completely isomorphous, the composition of the minerals being:

Beudantite	$\text{PbFe}^{III}_3(\text{OH})_6(\text{SO}_4)(\text{AsO}_4)$
Jarosite	$\text{KFe}^{III}_3(\text{OH})_6(\text{SO}_4)_2$
Plumbojarosite	$\text{PbFe}^{III}_6(\text{OH})_{12}(\text{SO}_4)_4$

This appears to be the first occasion on which either beudantite or plumbojarosite has been found in Australia.

(5) CALCIOSAMARSKITE, HILLSIDE*, N.W.

In 1928 H. V. Ellsworth described a mineral from Hybla, Ontario, which differed from samarskite by the displacement of most of the ferrous iron by lime. For this new species he suggested the name calciosamarskite. Both this and samarskite appear to belong to the euxenite group, of which the chief members are:

Yttrotantalite	$\text{Y}_2\text{Ta}_2\text{O}_8$
Polycrase	YTi_2NbO_8
Tantalopolycrase†	YTi_2TaO_8
Euxenite	$\text{YTi}_2\text{NbO}_8 + \text{Y}_2\text{Nb}_2\text{O}_8 (+ \text{CaTiNb}_2\text{O}_8, \text{ etc.})$
Tanteuxenite	$\text{YTi}_2\text{TaO}_8 + \text{Y}_2\text{Ta}_2\text{O}_8 (+ \text{CaTiTa}_2\text{O}_8, \text{ etc.})$
Samarskite	$\text{Y}_2\text{Nb}_2\text{O}_8 + \text{Fe}^{II}\text{U}^4\text{Nb}_2\text{O}_8$
Calciosamarskite	$\text{Y}_2\text{Nb}_2\text{O}_8 + \text{CaU}^4\text{Nb}_2\text{O}_8$

In each of these minerals there are a large number of isomorphous displacements, *e.g.*, Ta-Nb, Y-Er, etc., Ti-U-Zr, Fe^{II} - Mn^{II} -Ca. Autoxidation converts much, if not all, of the U^4 into U^6 in early Precambrian minerals of the group. Up to the present calciosamarskite has only been recorded from two localities, viz., Hybla and Parry Sound, both in Ontario.

The rapid rise in the price of tantalum ores in 1936-7 stimulated prospecting for such minerals in Pilbara, and as a result calciosamarskite was found four miles N.W. of the homestead on Hillside Station. It formed the greater part of a pebbly alluvial concentrate, its associates being microlite, an undetermined phosphate, iron ores, quartz, and microcline. It was doubtless originally formed in one of the numerous tantalum-bearing pegmatites which occur throughout this region.

*Lat. $21^\circ 45'$ S., Long. $119^\circ 25'$ E.

†Known in Western Australia but previously included under Euxenite or Tanteuxenite.

In composition, and physical and chemical properties, it closely approximates Ellsworth's descriptions of the Canadian minerals. An imperfect analysis showed :

Nb ₂ O ₅ , Ta ₂ O ₅	Y ₂ O ₃	CaO	FeO	MnO	PbO	UO ₃	TiO ₂
58.3	16.5‡	6.0	3.5	1.0	2.0	8.0§	1.0
SnO ₂	H ₂ O	Total	G				
2.6	2.0	100.9	5.60				

‡Includes a little Ce₂O₃.

§Includes traces of BeO and UO₂.

The pebbles range in weight up to 10 grammes. The surface has a thin coating of light grey to brownish alteration products, but on a fresh fracture the mineral is brownish black with a resinous lustre. It has a hardness of 5½. The specific gravity was determined on 20 more or less thinly coated pebbles. It ranged from 5.73 to 5.03, with an average of 5.60. The two lightest pebbles with G, 5.25 and 5.03 were probably more weathered or more hydrated than the others. The carefully cleaned piece used for analysis had the average specific gravity.

Under the microscope the powder has a maximum translucency of about 0.3 mm. The colour of the more transparent granules is olive brown, and they are, like so many hydrated rare earth minerals, abnormally isotropic. In a closed tube the mineral decrepitates energetically when heated, and yields a little water without melting.

The spot where this mineral was found is only seven miles from Eleys where monazite, tanteuxenite and tantalopolycrase occur ; and twelve miles from Cooglegong where monazite, gadolinite, hydrogadolinite, metagadolinite, hydroallanite, tanteuxenite and yttrotantalite have been found.

Reference : 1928. Ellsworth. *Amer. Min.* 13, p. 63-8.

(6) CHRYSOTILE—ANTIGORITE, MEILGA*, N.W.

The very highly priced chrysotile, exported to England from the Silver-sheen Asbestos Mine on Meilga Station in the valley of the Henry River, occurs under unique conditions. Practically every other known occurrence of commercial chrysotile is in an intrusive mass of serpentine, representing a metamorphosed peridotite or hypersthene. The Meilga mineral occurs in a Precambrian sedimentary dolomite along the walls of one or more intrusive dykes of typical fresh augite-labradorite dolerite without olivine. The marmorised grey dolomite close to one of the dykes, has been converted by hydrothermal action over a width of about 15 feet, into an almost pure massive antigorite, slightly contaminated on the actual contact with calcite and one or two as yet undetermined minerals. The chrysotile occurs in almost horizontal groups of veins forming networks in this antigorite, the veins yielding cross fibre from a few millimetres to 10 centimetres (one sixteenth to 4 inches) in length. The two widest veins measured were 10 and 12 cm. in width, with the usual planes of parting at 4 and 3 cm. from one wall respectively, but veins are said to have been seen in the mine up to 15. cm (6 inches) in width.

*Lat. 23° 0' S., Long. 115° 50' E.

Analyses of the massive antigorite and fibrous chrysotile are given below :

	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	MnO	MgO	CaO	
(1) Chrysotile best ...	41·93	·23	tr.	·43	·05	41·99	·03	
(2) Chrysotile 2nd grade	40·71	·08	·86	nil	tr.	31·85	8·21	
(3) Antigorite	41·95	·29	tr.	·34	·06	42·76	nil	
	H ₂ O+	H ₂ O—	CO ₂	Alks.	Total.	G.	Analyst.	
(1) Chrysotile best ...	13·47	1·17	1·34*	nil	100·64	2·37	Rowledge.	
(2) Chrysotile 2nd grade	8·78	1·62	7·71†	nil	99·82	2·52	Rowledge.	
(3) Antigorite	13·81	·87	nil	nil	100·16‡	2·48	Grace.	
				*	†			
*† Equal to CaCO ₃	...	...	...	·05	14·65			
MgCO ₃	...	...	...	2·53	2·43			
‡ Includes TiO ₂	...	...	...	·01				
P ₂ O ₅	...	...	...	·07				

The antigorite which forms the matrix of all the chrysotile veins is homogeneous, massive and translucent, often highly so, resembling wax or hard soap. Its colour is mostly pale cream, but some is almost white, whilst other specimens are of various shades of light amber and pink, to a dirty yellowish grey in rare instances. Even the latter shows diffuse daylight through a thickness of one centimetre, but some of the whitest antigorite is less translucent, probably owing to the presence of diffused microscopic granules of calcite.

The chrysotile too, though quite white in all cases when teased out, ranges in colour when in mass from pure white, through pale yellow and pink, to deep amber and reddish amber, most of the colours being elusive owing to the high translucency and chatoyance of the specimens, no Ridgway standard coming near them as a rule. Rarely some of the fibre embedded in the darkest coloured antigorite approaches a bronzy brown in certain lights. There is no tinge of green in any of the chrysotile. Very beautiful specimens are found of cream coloured waxy antigorite traversed by small anastomosing veins of salmon pink chrysotile with end faces of "apricot buff" to "apricot orange" (R. 11'b—11') where the butt end of the asbestos has broken cleanly away from the antigorite matrix. Other notable specimens have a matrix of translucent antigorite shading from faintly greenish yellow to dark brownish grey, traversed by veinlets of soft translucent chrysotile with a chatoyance changing from bronze brown to golden yellow. The translucency for diffuse daylight of this dark chrysotile is at least one centimetre in the direction of the fibre, but only half that across it. That of the bright reddish amber is over five centimetres along the fibre and 1·5 to 2·0 across it.

There is no constant relationship between the colour of the veins in mass and their commercial value, which depends on the fineness, flexibility and tensile strength of the separated fibres. Some of the best mineral, sold at £150 a ton, has been pure white, but almost equally valuable fibre has been coloured various tints of amber to reddish orange. The darkest fibre has usually been brittle and comparatively harsh, but so has some of the palest coloured. The analyses show that even the purest and most translucent specimens have extremely thin invisible films of calcite, dolomite, and magnesite along the fibres. Where these do not form more than 2 or 3 per cent of the whole, they have not been found to reduce the market value.

(7) CORDIERITE—ANTHOPHYLLITE, CLACKLINE*, S.W.

In 1937 Mr. F. G. Forman, Government Geologist, found a very unusual looking crystalline rock about one mile N.W. of the railway station. This I have since examined both in the field and in the laboratory. It forms a small lens, possibly a laccolite, flanked on either side by Precambrian sillimanite-quartz-biotite schists which are almost vertically bedded. The outcrop measures only about 100 x 20 feet, and there is no other similar outcrop anywhere near it. A few hundred yards to the north, and about the same distance to the south, gneissic granite cuts across the bedding of the metasediments.

The laccolite is composed of a rather coarse grained grey and slightly gneissic rock composed of equal parts of brownish white anthophyllite and grey to dull blue cordierite. The balance of the rock, about five per cent. of the whole, consists of chlorite, sericite, rutile and chromite. The only similar rock of which any account can be found is one in Finland, described by P. Eskola in 1914, and thought to be a "pneumatolytic metamorphic rock"

The "anthophyllite-cordierite granulites" in Cornwall described recently by C. E. Tilley, and the quartz-cordierite-anthophyllite rock in Sweden described by W. Larsson, appear to be different in nature and origin to the Clackline rock. They are much more siliceous (SiO_2 65.7 and 67.5 per cent.), and contain quartz and sodic plagioclase as important constituents.

The chemical composition of the Clackline rock is as follows:—

Cordierite—Anthophyllite Rock, Clackline.

SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O		
52.66	13.99	2.15	7.08	.12	20.20	.25	.08		
K_2O	$\text{H}_2\text{O}+$	$\text{H}_2\text{O}-$	TiO_2	CO_2	P_2O_5	FeS_2	Cr_2O_3	Total	G
.06	3.33	.13	.36	.02	.05	nil	.19	100.67	2.89

Analyst: H. P. Rowledge.

The calculated norm is:

Qtz	Cor	Or	Ab	An	Hyp	Mgt	Crm		
16.63	13.47	.33	.68	.89	60.97	3.13	.27		
				Ilm	Ap	$\text{H}_2\text{O}+\text{CO}_2$	Total		
				.68	.13	3.48	100.66		

Both chemical composition and norm are unique for a West Australian rock.

The cordierite for the most part forms anhedral grains from 1 to 3 mm. in length. At rare intervals dull blue or violet masses of pure cordierite up to nearly 10 mm. in diameter are visible in hand specimens. In a thin slice under the microscope the mineral appears colourless and transparent, is devoid of crystal boundaries or cleavages, and encloses a small amount of minute dusty granules, and an occasional small crystal of anthophyllite or rutile. Veinlets of sealy chlorite and sericite traverse the mineral in an irregular network, but form only a very small proportion of the whole, which is unusually fresh and free from deep seated or surface alteration.

The associated anthophyllite is idiomorphic, forming prisms from 0.05 to 5 mm. in length, pale brownish amber in mass, but colourless under the microscope. The crystals show the characteristic high birefringence, straight extinction and positive elongation.

*Lat. 31° 45' S., Long. 116° 32' E.

The origin of the rock is obscure, but I am inclined to consider it as a laccolite closely related to the numerous hypersthenite dykes which occur within a 25-mile radius, the magma having been altered by absorption of some slate or similar aluminous rock.* The high percentage of magnesia, and presence of appreciable chromium is significant in this respect, as is also the low proportion of lime and alkalis.

References: 1914. Eskola, *Bull. Comm. Geol. Finlande*, 40, p. 169, 187, 252.

(Abs. 1928. A. Holmes, *Nomenclature of Petrology*, p. 69.)

1932. Larsson, *Bull. Geol. Inst. Upsala*, 24, p. 118.

1937. Tilley, *Geol. Mag.* 74, p. 300-9.

(8) FAYALITE—HEDENBERGITE, BURGESS FIND†, S.W.

A unique type of gabbro has been found at Burgess Gold Find, ten miles south of Burracoppin. It forms a dyke associated with Precambrian amphibolite and metasediments in an area almost surrounded by granite.

The rock is a very fresh, coarse grained mixture of labradorite, hedenbergite, hornblende, fayalite, apatite, magnetite, ilmenite, and pyrite. Its composition is:

Fayalite-gabbro, Burgess Find.

SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	MnO	MgO	CaO	Na ₂ O	K ₂ O	H ₂ O+
40.18	7.90	6.34	27.38	.70	.70	10.91	1.20	.24	.10
H ₂ O—	TiO ₂	CO ₂	P ₂ O ₅	FeS ₂	Cr ₂ O ₃	V ₂ O ₃	Total	G	
.17	2.51	.11	.68	.66	nil	.05	99.83	3.47	

Analyst: J. N. A. Grace.

The extraordinarily high molecular ratio of FeO to MgO (23 to 1) indicates that the chief ferromagnesian minerals are the unusual species, fayalite (Fe₂SiO₄) and hedenbergite (CaFeSi₂O₆).

Microscopic investigation confirms this. In section the fayalite is in large rounded transparent grains, traversed by many cracks, and showing a high birefringence and slight pleochroism, light yellow (β) to very pale greenish yellow (α , γ).

The hedenbergite is in more angular, but rarely idiomorphic grains, showing the prismatic cleavage plainly. The mineral is much less transparent than the fayalite, and is weakly pleochroic; α , medium bottle green; β , yellowish green; γ , deep bottle green. The maximum extinction angle measured was 48°.

This is the first record of these two minerals for Western Australia.

References: 1936. W.A. *Chem. Branch An. Rept.* 1935, p. 6.

1936. W.A. *Geol. Surv. An. Rept.* 1935, p. 34.

(9) PETALITE, LONDONDERRY‡, Cen.

In 1933 the writer inspected Seahill's Felspar Quarry on M.L. 72 (now 80) at Londonderry, and found a few small cores of slightly altered petalite embedded in large masses of a quartz-chalcedony pseudomorph. This occurrence was described in Series VIII. of these Contributions.

*Thus: $9\text{MgSiO}_3 + 2\text{H}_4\text{Al}_2\text{Si}_2\text{O}_9 \rightarrow \text{Mg}_2\text{Al}_4\text{Si}_5\text{O}_{18} + \text{H}_2\text{Mg}_7\text{Si}_8\text{O}_{24} + 3\text{H}_2\text{O}$
 Enstatite Kaolin Cordierite Anthophyllite Water.

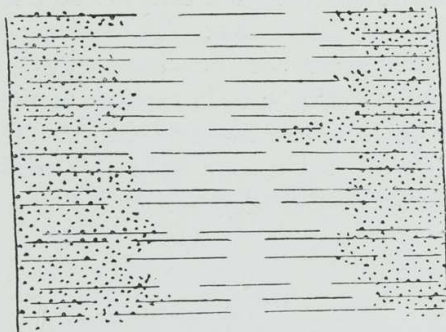
†Lat. 31° 35' S., Long. 118° 30' E.

‡Lat. 31° 5' S., Long. 121° 7' E.

In October, 1937, a further inspection of the quarry was made. The felspar (microcline) vein was then being exploited energetically by Australian Glass Manufacturers, Ltd., and the quarry had reached a depth of 45 feet with a width and length of over 100 feet.

It was immediately apparent that much of what the quarrymen had been taking for quartz, and throwing away on the waste dump, was in reality petalite. Many tons of it were to be seen in the north face of the quarry and in the dump, where also were large quantities of various pseudomorphs after it, apparently originating in the latest stages of vein development.

About one-quarter of the whole rock broken in the quarry is clean white microcline, which is shipped to factories in the Eastern States. Other common constituents are quartz, albite, petalite, pseudomorphs after petalite, lepidolite, beryl and spessartite. An occasional crystal of manganocolumbite has been found. The petalite occurs mostly if not wholly in veins or in lenses, one inch to two feet (2 to 60 cm.) in width in the pegmatite. These veins, in almost every case, are completely filled with uncontaminated petalite or pseudomorphs after it. The exceptions are where a later quite small fissure in the petalite is filled with albite and lepidolite. The same two minerals frequently form the walls of petalite veins.



Petalite vein, Londonderry, converted along the walls into an Albite-Chalcedony Pseudomorph.

Fig. 4.

The vein fillings consist either of pure unaltered petalite, of petalite partly replaced by pseudomorphs against one or both walls (Fig. 4), of small pieces of petalite with ragged boundaries completely surrounded by a pseudo-

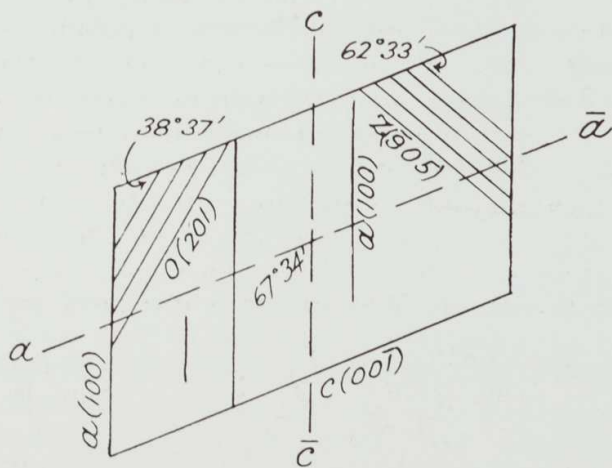
ERRATUM.

Page 116, second line from bottom, for "quartz-chalcedony pseudomorph," read albite-chalcedony pseudomorph.

The purest mineral is water white and perfectly transparent up to 1 cm. or more. It has a hardness of $6\frac{1}{4}$, specific gravity 2.41 and the composition shown in Col. 1. The majority of specimens however show white streaks

or clouds of less translucent mineral, probably due mainly to the presence of minute fluid inclusions. Frequent air filled cleavages also help to interrupt the light. The composition of some of the slightly cloudy mineral is given in Col. 2. This original analysis was made in 1933 on a very small core of cloudy petalite completely embedded in albite-chalcedony pseudomorph, and may have been slightly contaminated with decomposition products.

The cohesion of the pure mineral is of interest. The masses of it are considerably fissured by cleavages and partings. Always prominent is the basal cleavage, described in the text books as "perfect" or "vollkommen." It is not, however, perfect in the sense that the cleavage of mica, gypsum, or galena is so described, as although it is very prominent, and of broad uninterrupted extent, the mineral shows no inclination to part in repeated thin layers even under considerable side pressure or impact. On the contrary it is more like a parting than a cleavage, as it is unevenly spaced, and when broken at right angles to it, the mineral yields large uninterrupted conchoidal or subconchoidal surfaces 1 to 10 mm. wide between the cleavage traces. This cleavage is always at right angles to the walls of the veinlets, and probably owing to pressure from them, in some specimens shows a few slight changes of direction amounting to one or two degrees, resembling those produced by multiple twinning in such minerals as plagioclase or amblygonite. The finest specimens give such a brilliant reflection from the broad basal cleavages as to resemble colourless topaz, and it has been suggested to me that such specimens might be cut into gems. A $2\frac{1}{2}$ carat brilliant cut from such material was perfectly transparent and flawless, and of considerable brilliancy. It lacked fire however, owing to the low dispersion of petalite, viz. $b-r=0.010$. In these specimens there is often no indication of any other parting or cleavage. Usually, however, the traces of innumerable cross fractures are visible, giving a rougher and duller appearance to the basal plane.



Petalite, Londonderry. Projection on $b(010)$, showing minor cleavages, the prominent basal cleavage omitted.

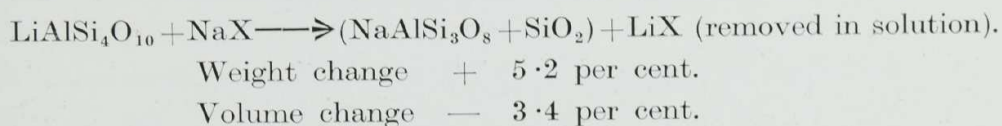
Fig. 5.

Quite strongly developed in some specimens is a series of partings at right angles to $c(001)$ and parallel to $b(010)$. Other less frequent and distinct partings are $a(100)$, $a(210)$, and $z(905)$, making angles with c of $+67\frac{1}{2}^\circ$, $+38\frac{1}{2}^\circ$, and $-62\frac{1}{2}^\circ$. (See Fig. 5.) In consequence of the multiplicity of

such partings certain specimens have a cross hatched appearance on their surfaces. The infiltration of minute amounts of brown kaolin and limonite from the soil along the cleavages gives some specimens an amber tinge.

The Londonderry petalite before the blowpipe fuses on thin edges, and colours the flame red. In a closed tube it gives a red glow below normal red heat.

After the original deposition of the petalite, renewed fracturing of the pegmatite vein took place and strong sodium-bearing solutions penetrated them, upsetting the established equilibrium, and producing pseudomorphs after petalite, in accordance with the following equation:—



Subsequently the intimate microscopic intergrowth of albite and chalcedony this produced was further altered by hydrolysis, and addition of small quantities of potash, lime, magnesia, iron and manganese, with the formation of indeterminate mineral mixtures, including probably montmorillonite.

Three main types of pseudomorph are visible on the dump:—

- (A.) Hard ($6\frac{1}{2}$) white horny or porcellanous masses, showing remnants of the original basal cleavage.
- (B.) Much softer grey pseudomorphs, hardness 3 to 5.
- (C.) Lilac coloured pseudomorphs with a similar range of hardness, viz., 3 to 5.

(A.) This has previously been described in some detail (*loc. cit.*). An analysis of a typical specimen is given in Col. 3 of the accompanying table. It is a microcrystalline intergrowth of about 72 per cent. albite, 20 per cent. quartz, and 8 per cent. montmorillonite and sericite (?). Some very large homogeneous masses of this white opaque pseudomorph have been quarried. Other masses contain more or less small cores of petalite with hazy boundaries, and the basal cleavage continuing as a parting from the original mineral into the pseudomorph. Many instances were observed of one or both sides of a vein being converted into this pseudomorph, whilst the balance remained perfectly fresh, the surface of contact being very jagged. (Fig. 4.) In one specimen there are two veins separated by only 2 to 3 cm. of granular albite with some lepidolite. One vein, from 30 to 60 cm. wide, is completely altered into the albite-chalcedony pseudomorph, the other is perfectly unaltered, except for a very thin layer of albitised mineral on the inner wall.

(B.) The grey pseudomorph varies in colour from pale neutral grey to deep greenish grey (about R 35⁵). Occasionally there is a slight buff or purplish tinge in the grey. Rarely is the colour uniform, usually there are included in it rounded or streaky areas of white with indistinct boundaries. The hardness is lower than that of petalite or the white pseudomorph, hovering round $4\frac{1}{2}$. Some specimens have a slightly silky lustre, but mostly it is dull. The original basal cleavage of the petalite is represented by a strongly marked parting at wide intervals, or by a general foliated structure parallel to it. Rarely this pseudomorph surrounds a small remnant of petalite. It is quite complex in composition as the analysis in Col. 4 shows, and it is to be noted that there is a little lithia left in it. It is usually found not far from a concentration of lepidolite with spessartite and albite, and evidently indicates some unusual and purely local conditions during alteration.

(C.) The lilac coloured pseudomorph, like the grey, is seldom homogeneous as regards colour or hardness. The latter ranges round 4. The commonest colour is between "mauvette" (R 65'f) and "lilac" (R 65'd). Some of it is paler and more pinkish. This pseudomorph is found both as ragged inclusions in the white pseudomorph (A.), as mottled mixtures with it, and finally as large almost homogeneous, masses. The original basal

Petalite, Londonderry.

No.	1 Petalite, colourless transparent.	2 Petalite, colourless milky.	3 Milk white hard pseudomorph. ‡	4 Olive grey pseudomorph.	5 Lilac pseudomorph.	6 Lilac pseudomorph.
SiO ₂	78.68	76.19	74.48	78.26	77.83	72.60
Al ₂ O ₃	16.62	16.48	15.52	13.34	14.93	16.64
Fe ₂ O ₃	.09	.21	.17	.93	.14	traces
FeO	nil	nil	nil	.46	nil	nil
Mn ₂ O ₃	.004	trace	nil	.31	.20	0.67
MgO	nil	.54	.11	.28	.31	.37
CaO	nil	nil	.20	.26	.54	1.32
BeO	spec. tr.*	?	?	spec. tr. †	?	present
Li ₂ O	4.13	3.72	nil	.64	1.11	.94
Na ₂ O	.08	.36	7.72	.36	.10	.68
K ₂ O	nil	.18	1.22	.18	nil	.25
H ₂ O+	.01	1.04	.40	4.49	4.48	5.76
H ₂ O—	nil	1.22	.50	.84	.55	n.d.
Total	99.834	99.94	100.32	100.35	100.19	99.23
G	2.41	2.38	2.61	2.615	2.60	...
H	6	6	7	4-5	3-5	...
N	...	1.514, .510; .502	...	...	...	...
Analyst	H. P. Rowledge	C. R. Le Mesurier	C. R. Le Mesurier	D. G. Murray	C. R. Le Mesurier	H. Bittner

* BeO, less than 0.02 per cent. † BeO, less than 0.004 per cent. ‡ Another specimen had SiO₂, 72.35, G; 2.64.

cleavage of the petalite is easily distinguished in the harder specimens as a more or less widely spaced parting, but is not so conspicuous in the softer and presumably more altered ones. The composition is again very complex, as shown by the two analyses in Cols. 5, 6. The lithia found is undoubtedly present in remnants of original petalite, of which innumerable small specks in optical continuity are embedded in the decomposition mixture. The lime and magnesia are probably present as montmorillonite, whilst the Mn_2O_3 , which is derived from adjacent lepidolite and spessartite, or the solutions which generated them, replaces part of the alumina of the montmorillonite to which it imparts the lilac colour.

This occurrence on M.L. 80 at Londonderry is undoubtedly one of the most remarkable deposits of petalite in the world.

Two miles north of it, in the same belt of Precambrian amphibolite, are some small tin and tantalum workings at what was once known as Mercer's Find. In 1937 a pegmatite vein on abandoned M.L.61 was opened up to a depth of about 10 feet in search of manganotantalite. The vein consists mainly of quartz, albite, microcline and a very dark botryoidal lepidolite or zinnwaldite. On the dump the writer observed a few fragments of a pseudomorph after petalite, which were traced to one or two small secondary veins in the pegmatite. These veins were only 3 to 6 cm. wide and were wholly filled with the pseudomorphs. No unaltered petalite was seen, but the alteration products are identical with some of those in the quarry on M.L. 80. The colour varies from white to lilac on the one hand, and through pale neutral grey to greenish grey or olive grey on the other. Both types have the same specific gravity, 2.53, with a hardness ranging from $4\frac{1}{2}$ to $5\frac{1}{2}$. The white material forms cloudy patches in the coloured. It is not as hard and dense as the porcellanous white material in M.L. 80. A strong parting is continuous across the veins, being undoubtedly the relic of the basal cleavage of the original petalite, which further mining operations may expose.

Reference: 1933. Simpson, *Jour. Roy. Soc. W.A.*, Vol. 20, p. 58-9.

(10) SPODUMENE, McPHEES RANGE*, N.W.

The opening up of a new tantalum vein near Pilgangoora Trig. Station (CC 32) has revealed the presence of a considerable amount of spodumene. The vein is a pegmatite (in Precambrian greenstone) of which quartz and albite are the principal constituents. Cassiterite, manganocolumbite and manganotantalite are irregularly distributed through it, as also are spodumene, beryl, garnet, biotite, lepidolite and muscovite. It was observed by H. Bowley in samples submitted for assay that wherever spodumene was present, the tantalum minerals were abundant, and cassiterite comparatively rare. In some specimens the small crystals of tantalum mineral are completely embedded in spodumene.

The spodumene is said to be found at times in very large masses in the veins. In specimens brought to Perth it is visible in imperfect crystals, up to 10 x 5 cm., with strong prismatic cleavage. The forms developed are usually *a* and *m*. No terminal faces were recognised. The colour ranges from milk white to pale neutral grey, or pale purplish grey (R 67^d). The translucency for diffuse daylight reaches 4 mm. in some specimens, but is usually a little less. The maximum refractive index is about 1.68, extinction angle 28°, and elongation positive. The specific gravity is 3.10 to 3.14.

* Lat. 21° 5' S., Long. 118° 55' E.

The composition of a typical piece was found to be normal, the figures being :

SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	Mn ₂ O ₃	CaO	MgO	Li ₂ O	Na ₂ O
63·83	27·34	·15	·08	·22	nil	7·08	·44
K ₂ O	TiO ₂	CO ₂	P ₂ O ₅	H ₂ O+	H ₂ O—	Total	Analyst—
·22	nil	·10	·06	·18	·06	99·76	C. R. Le Mesurier

In one part of the vein some interesting pseudomorphs have been collected. These consist of dense masses of microscaly muscovite, preserving the external faces of the original spodumene and at times, like the unaltered spodumene, enclosing pieces of tantalum ore. They range in colour from light vinaceous grey (R. 69^d) to near vinaceous purple (R. 65³), the colour being doubtless due to Mn₂O₃. A determination of the alkalis showed :

	Li ₂ O	Na ₂ O	K ₂ O	Sp. Gr.
Per cent	0·10	·22	8·12	2·81

This is another instance of the latest stages of pegmatite formation being characterised by the invasion of highly active potassic solutions. In veins at Melville and Londonderry under such conditions large masses of topaz have been altered to a considerable depth into cryptocrystalline muscovite, whilst at Melville and Westonia large masses of cordierite have been almost entirely altered into muscovite.

Acknowledgments.—I desire to acknowledge my indebtedness to the Government Geologist, Mr. F. G. Forman, for three of the specimens herein described, and to Messrs. J. N. A. Grace, C. R. Le Mesurier and H. P. Rowledge of the Government Laboratory for making several analyses for me.